CHAPTER 7

AUTOMATIC CONTROLS

Section I. GENERAL

7-1. Types of controls and control systems.

Standard controls, as furnished for automatic fuel burning equipment, come in sets for steam, hot water and warm air systems. The standard automatic control set consists of thermostats and primary, limit, and auxiliary controls. Following are the types of control systems used for heating installations:

a. *Pneumatic controls.* In this type system, air at relatively low pressures (15 to 25 pig) is used to motivate the primary control. Air for pneumatic control systems is usually produced by a centrally located compressor and is distributed throughout a building through plastic or metal tubing.

b. *Electric controls.* In this type system, electric energy at line or reduced voltage is used to motivate the primary control. This type of control system is the one most commonly used with small heating equipment.

c. *Electronic controls.* In this type system, solid state controllers operating at line or reduced voltage produce a low voltage signal for control of elector-hydraulic actuators or similar equipment. Newer electronic control systems contain microprocessors which are programmed at the factory to perform a number of control functions. These control systems are not generic, they differ from one manufacturer to another, and operating and maintenance information should be obtained from the manufacturer for each individual control system.

7-2. Thermostats.

a. A thermostat is a device that senses the surrounding temperature and activates the primary controls of the heating system whenever heat is required to maintain a predetermined temperature. Thermostats in electric or electronic control systems are either low voltage, designed to operate on 25 volts or less, or they are line voltage thermostats, designed to operate directly from a 110 volt line. Thermostats operating directly from 220 volt lines are not normally used. Line voltage thermostats can directly control heating equipment with capacities within their ratings; low voltage thermostats actuate relays which control the equipment. Usually in high capacity installations, the thermostat sends a signal to actuate a primary control instead of actually controlling equipment.

b. Thermostats fall into two main categories in heating system applications:

(1) *Room thermostats.* Room thermostats are placed directly into the space to be heated. As space temperatures fall, these thermostats signal the heating system to provide more heat to the space.

(2) *Outdoor-reset thermostats.* In reset systems, a thermostat located outdoors lowers the temperature of hot water supplied from a boiler as the temperature rises outside. This type of system prevents the building from overheating if individual room controls are not used. This system can also save energy by reducing the load on the boiler.

7-3. Primary controls.

Primary controls are sensors and actuating devices that directly operate the heating unit in accordance with demands of the space thermostat. Primary control systems usually consist of a sensor for the heating fluid (steam pressure, air or hot water temperature) and a device to actuate the burner or gas valve.

7-4. Limit controls and safeties.

Limit controls and safeties prevent the heating equipment from operating if a condition exists which is harmful to the equipment or to people. A limit control is a device capable of shutting down the heating unit whenever the temperature or the pressure of the unit exceeds a preset limit. Safeties detect the presence of unsafe conditions such as no flame, low water level, or low gas pressure, and prevent the equipment from firing.

Section II. OPERATION AND MAINTENANCE

7-5. General.

Controls must be carefully handled, properly installed and kept in proper adjustment to obtain good heating system performance. Inspect controls on a regular basis to ensure that they have not been tampered with and that they are operating correctly. This is essential for safety, comfort and energy

efficiency. When installing and maintaining controls, keep the following in mind:

a. Permit only authorized personnel to adjust or change control settings. Thermostats should be installed with locking covers or in hidden locations such as return air plenums to minimize tampering by unauthorized personnel.

b. Obtain installation and maintenance manuals on controls, from the control manufacturer. These manuals facilitate installation, testing and adjustment.

c. Always read the manufacturer's instructions which are usually packed with each control, before installing, setting, or adjusting the control. Keep these instructions for future reference.

d. Always be sure that a control or control system is correctly wired according to manufacturers' wiring diagram.

e. After installing and adjusting a control, be sure to replace and secure all covers.

7-6. Thermostats.

a. A thermostat (figures 7-1 and 7-2) measures the temperature of the air circulating around it. It is also affected by the temperature of the wall on which it is located. Always install a thermostat on an inside wall at eye level and in a place where it will be affected by the average room temperature. Make sure that there is free circulation of air at the point of mounting and that the thermostat is unobstructed by furniture, doors, lockers, and the like. Do not mount a thermostat where the sun's rays will strike it at any time. In barracks, a centrally located supporting post or column affords a satisfactory thermostat location. In officer's quarters or in office buildings, the inside wall of a representative room will provide a satisfactory location. Avoid hallways whenever possible.

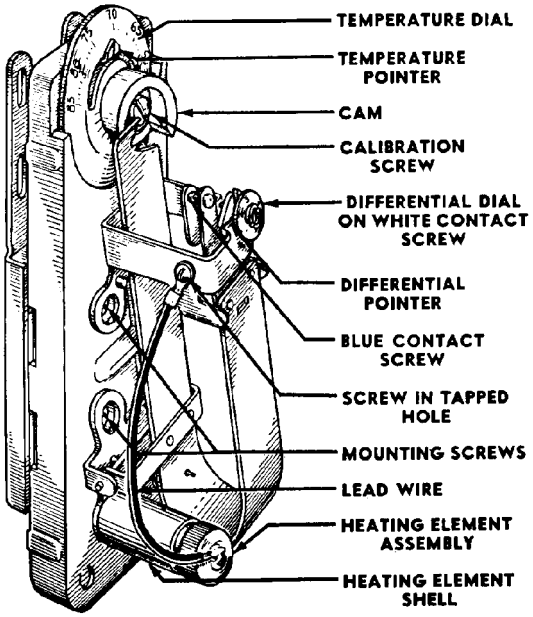

Figure 7-1. Metal element thermostat.

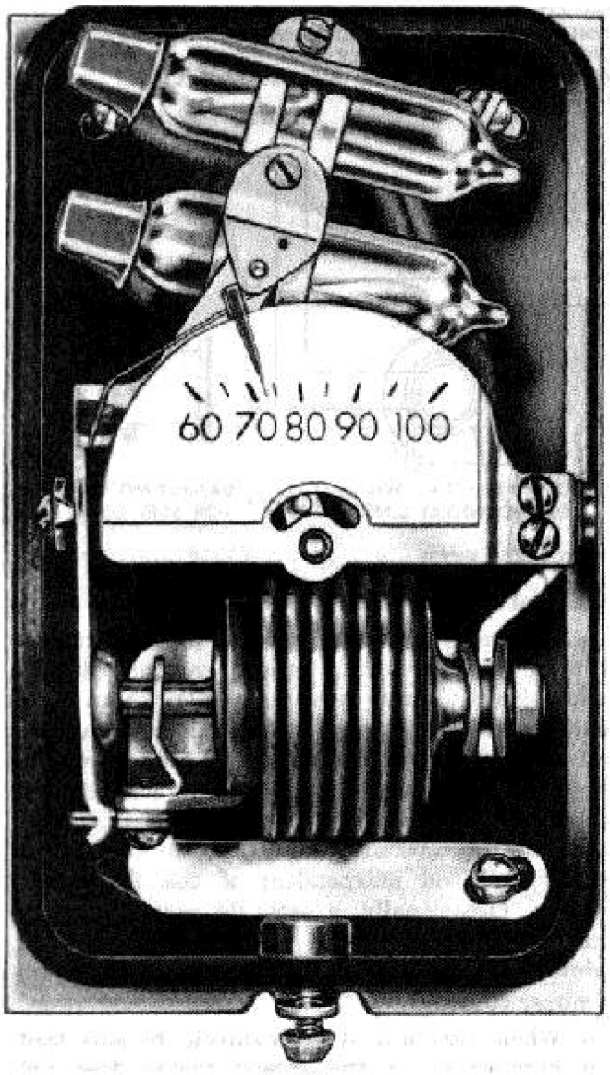

Figure 7-2. Mercury switch thermostat.

b. Permit no one but authorized personnel to make adjustments. Make adjustments to thermostat setpoint in small gradual steps waiting for at least two cycles of operation, usually about 1 to 1 1½ hours, before judging the new accuracy of performance.

c. When dust or dirt accumulates on the contacts of a thermostat, preventing proper operation of the control, clean contacts by holding them together lightly between the fingers, and draw a piece of hard finish paper, such as a common business card, between them. Never use emory cloth or abrasives.

d. Some heating thermostats are equipped with a device called an anticipator. This is a small heater located near the temperature sensing element that is energized when the thermostat activates the heating system. The purpose of the anticipator is to give a false signal to the thermostat, shutting off the heating system before the thermostat setpoint is reached. The heat built up within the heating system ductwork continues to enter the space, raising the space temperature toward the setpoint without overshooting it. Anticipators are adjusted by measuring the amperage through the thermostat with the heating system on and setting the dial on the anticipator to the measured amperage.

7-7. Hand-fired coal primary controls.

a. The common type of hand fired primary control, except where anthracite buckwheat blowers are used, is the electrically operated damper motor. In some instances a spring return motor will be used, but more frequently the electric return type will be found. The latter rotates the lever arm shaft 180 degrees to open and rotates the lever arm shaft another 180 degrees to close the damper. The spring return type rotates around 60 degrees to open, and closes by moving the arms in the opposite direction under action of a heavy external spring. It is common practice that a damper motor have a basement switch whereby the dampers can, when desired, be manually opened and closed. On buckwheat fired furnaces and boilers, the thermostat starts the blower or forced draft fan when heat is wanted. Figure 7-3 shows a typical wiring diagram for a hand fired furnace primary control.

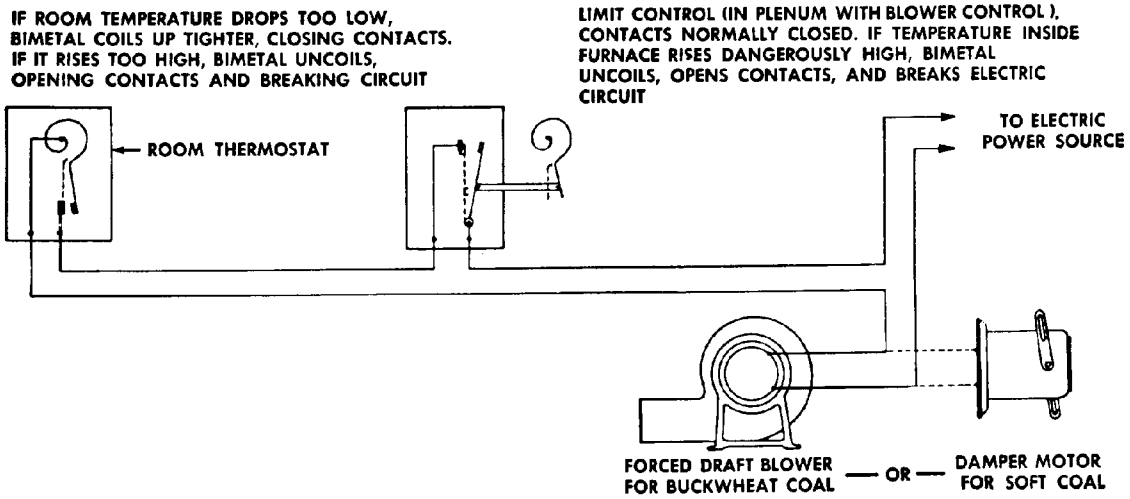

Figure 7-3. Coal furnace primary control wiring.

b. A less common type of hand fired primary control is hydraulic in action. Current from the thermostat passes through a heating coil which is wound around a liquid chamber. Heat of the coil expands the liquid. The liquid, by expanding bellows or piston action, exerts power necessary for a lever to operate the check and draft dampers by means of chains.

c. When installing, always check manufacturer's instructions to make sure the proper transformer is used.

d. Do not install the control directly over or so close to the furnace or boiler that heat dries out the motor oil.

e. Lubricate the motor at the beginning of each heating season and periodically during the season. Use a high grade, fine oil, but use it sparingly so that oil does not get on electrical contacts and the switching mechanism.

f. Be sure that damper arms are not overloaded.

g. Do not permit anyone to block check and draft dampers in either the open or closed position.

h. Be sure that damper chains and lever arms are properly adjusted.

i. Be sure that chain pulleys are lined up to prevent binding and sticking and be sure that lever arms are attached to give proper sequence in opening and closing dampers. Most damper arms are capable of four positions varying by 90 degrees each.

j. Always leave the basement switch in the automatic position after manual operation of the motor.

7-8. Coal stoker primary controls.

The essential function of a stoker primary control is to provide switching action which starts the stoker directly, or to serve as a relay to an automatic starter for a large stoker. The switching is activated by a room thermostat or other temperature or pressure regulating device. In addition, the stoker control includes a timing mechanism for intermittently operating the stoker to maintain a proper fuel bed independent of the thermostat demand. Occasionally, a separate switching relay and stoker timing device is used. The following points should be kept in mind for proper operation of stoker controls:

a. When installing stoker controls, be sure that the horsepower of the stoker motor does not exceed the electrical rating of the stoker control. Use manufacturer's control ratings.

b. Optional wiring may frequently be used when hooking up stoker controls. Be sure that all necessary jumper connections are made on the control at time of wiring.

c. Settings for frequency and length of hold-fire operations of the stoker by the stoker control, to maintain a proper fuel bed, are generally adjustable. Check to make sure that these settings are proper for the weather and type of fuel used.

d. Replace covers on all controls. This will keep out dust and dirt and prolong the life of controls. It will also reduce the number of service calls.

7-9. Oil-burner primary controls.

The oil burner primary control, (figure 7-4), consists essentially of a combination of four controls in one device: a relay, an ignition control, a delayed action switch, and an out fire cut-off switch.

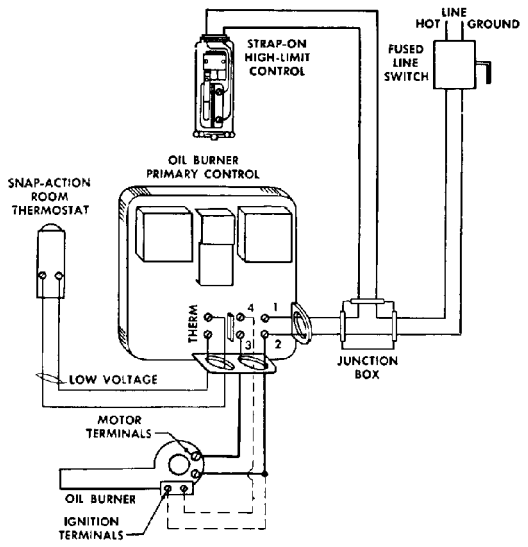

Figure 7-4. Oil burner primary control wiring.

a. The relay, activated by the thermostat, furnishes power to the oil burner motor and ignition transformer.

b. Ignition control may be one of two types, continuous or intermittent. In the continuous type, the ignition switch is omitted. Power to the ignition transformer is supplied directly from the relay which is activated by the thermostat.

c. The intermittent type of ignition control has an auxiliary switch which cuts off power to the ignition transformer at a predetermined stack temperature setting, after the burner is in proper operation.

d. The delayed action switch is a safety switch which prevents the burner from igniting, regardless of thermostat requirements, until the stack temperature has cooled to a temperature below the setting of the intermittent ignition control. In continuous ignition control, the delayed action switch delays power to the relay until stack temperature has cooled sufficiently to assure a cool combustion chamber. In either case, an oil explosion is prevented should the ignition fail to be in the off position.

e. Outfire control cuts power to the burner should the oil fail to ignite. This prevents flooding the combustion chamber with unignited oil. Modern burners use "electric eyes" to detect the presence of flame. Clean the flame sensor prior to each heating season to assure proper operation.

f. For best results, the oil burner control should be located in the stack as close to the furnace as possible where the stack temperature does not exceed 1000F. Many furnaces and boilers now operate at stack temperatures of from 400F to 600F and the controls have been designed to operate at or near this range with adjustments to adapt them to higher or lower temperature. Be sure to read and study manufacturer's installation instructions.

g. Be sure the actuating element at the end of the tube or element extension is inserted in the stack so that it is influenced by representative flue gas temperature. Avoid installation in sharp elbows and square corners where dead pockets form.

h. Do not block the burner motor or ignition relay switches in either the in or out position. The oil burner control incorporates safety features that will not be operative if any attempt at manual operation is made. If it is necessary to operate the oil burner manually, pull the line switch to the burner, then set the thermostat up to the high position and close the line switch.

i. Be sure to mount mercury switch types of oil burner controls level according to manufacturer's instructions to assure proper operation.

j. For controls which have sliding fingers on the push rod attached to the actuating element, a special fingertip lever is provided to place control in the proper sequence for initial startup. It is always desirable to use this device to get the proper control sequence. See instruction sheets furnished by the control manufacturer.

k. Be sure the hole made in the stack for insertion of the control element is properly sealed after installation of the stack control. Air leakage at this point results in faulty operation. Some controls have ventilating slots to compensate for high or low stack temperatures. See manufacturer s instructions for adjusting slots.

l. If the control causes a safety shut-down of the burner, do not restart the burner until the cause of the problem is determined.

7-10. Gas burner primary controls.

a. The primary control for a gas burner is a valve which opens and closes in response to a thermostat. Figure 7-5 shows a typical wiring diagram for a gas burner primary control. There are basically four types of gas valves, each type having a number of varieties. The four types are described below.

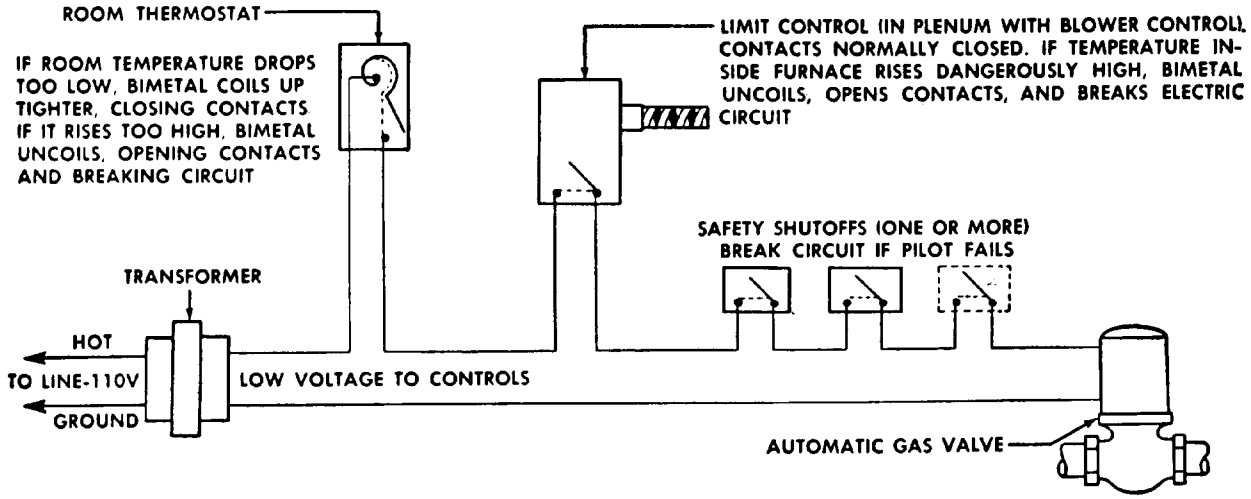

Figure 7-5. Gas burner primary control wiring.

(1) *Solenoid or magnetic, fast opening.* In the fast opening solenoid or magnetic valve, the valve is opened by electric energy applied to a solenoid which lifts a plunger. The solenoid acts as an electromagnet. The valve is closed by gravity and spring action when the electrical circuit is broken by thermostat or limit control.

(2) *Diaphragm, or slow opening.* Small, slow opening diaphragm valves are used on some smaller furnaces and boilers, but this type valve is usually used on larger installations where the gas supply pipe sizes are 2 inches or larger. Gas under pressure is admitted to the diaphragm by means of an electrically operated three-way pilot valve. When energized, the pilot valve bleeds gas off the top of the diaphragm which opens the main valve. When deenergized, the pilot valve equalizes pres sure above and below the diaphragm, and gravity causes the main valve to close. The speed of opening and closing is regulated by the size of the bleed line and ports in the valve. These valves are often equipped with external levers for regulating auxiliary air dampers built into the burner unit. Free action of the damper is essential to correct functioning of the valve.

(3) *Magnetic, medium speed opening.* In magnetic valves with medium opening speed, provision is made to communicate gas pressure from the main gas supply to the underside of the diaphragm at all times (figure 7-6). This gas pressure is also communicated up through Channel A and into Channel B. The magnetic control valve shown is in the deenergized position.

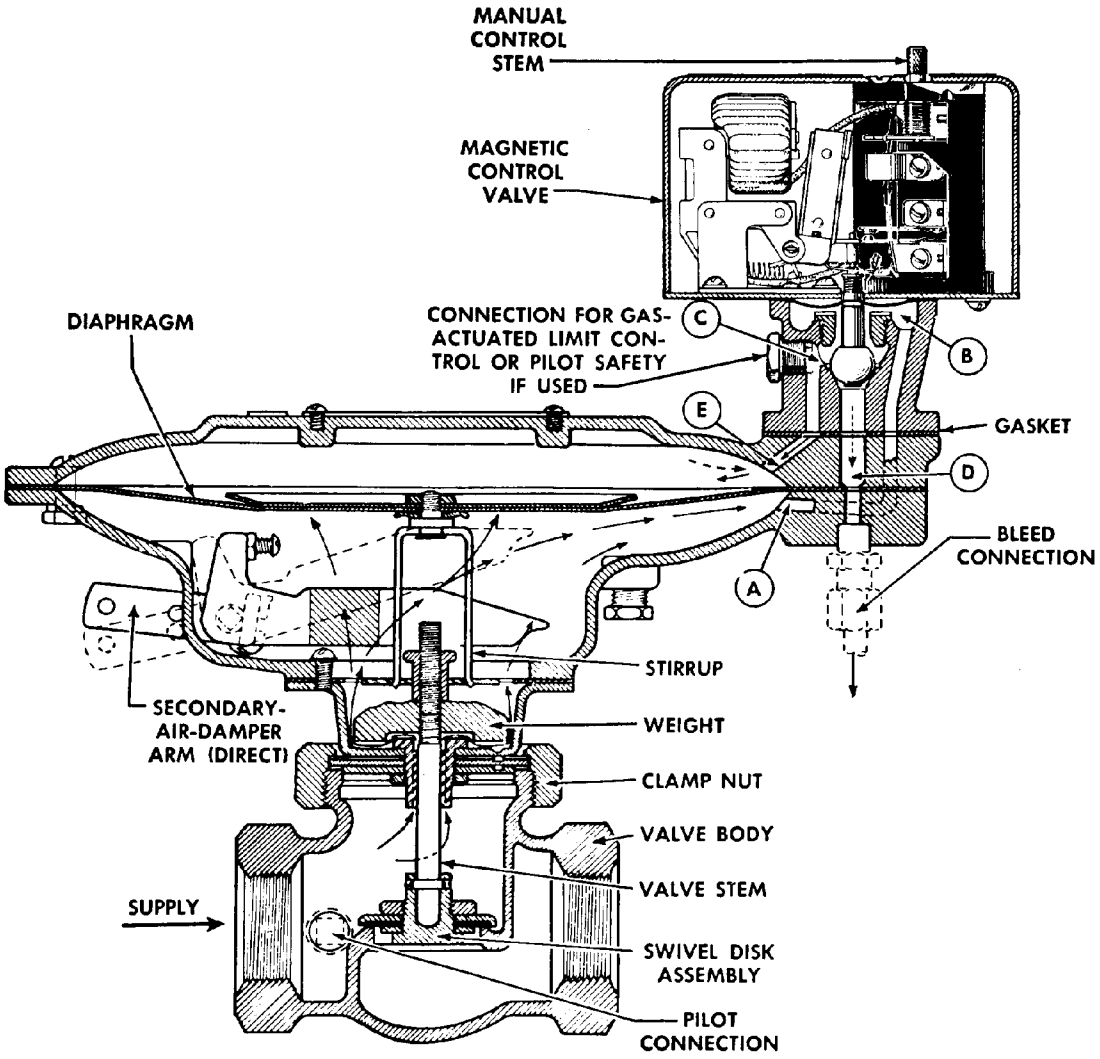

Figure 7–6. Magnetic diaphragm gas valve.

(4) Motorized, medium speed opening As the name implies, this type of valve has an electric motor unit mounted on top of the valve for opening. When energized, the motor holds the valve open in what is known as the stalled position. When the motor is deenergized, the valve is closed by a return spring. The motorized valve usually has a lever arm actuated on opening and closing of the valve which operates an auxiliary air damper. This type valve is often used on more expensive furnace and boiler installations and may range in size from ¾ inch to 2½ inches. Figure 7-7 shows a cross section of a typical motorized gas valve which controls the flow of gas to the burner. The power unit which operates this valve has two coil types. Both coils are energized on the lift and only the holding coil is energized when the valve is in the open position. If heat is desired during a period when current is not available, the gas valve can be operated manually.

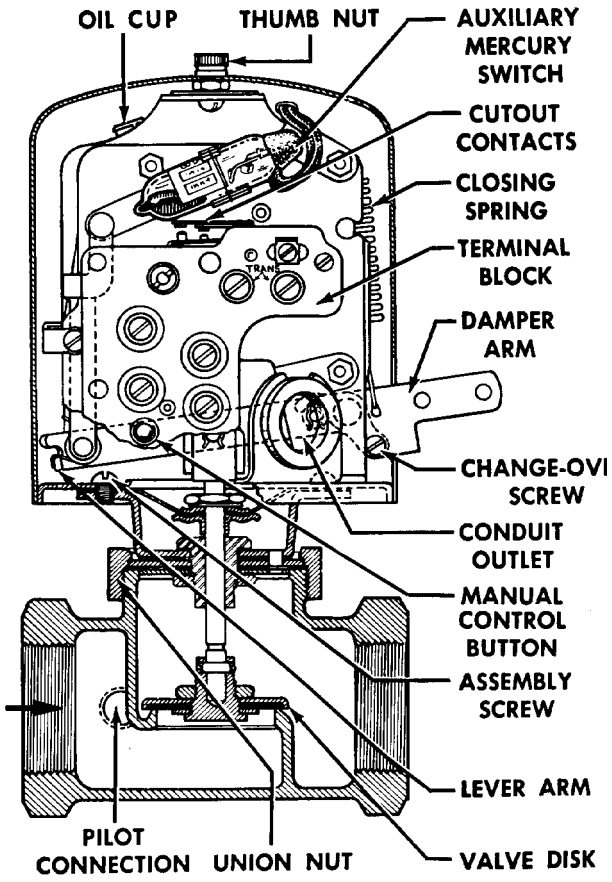

Figure 7-7. Motorized gas valve.

b. Pipe connections to gas valves must be tight. When applying pipe dope, do not apply it to the female threads in the valve. Apply dope to male pipe threads sparingly and leave the first two threads bare.

c. Some valves are equipped with a manual opening device for use in case of power failure. Do not block or otherwise lock valves in manual open position since valves are generally equipped with a recycling feature by which the thermostat returns to automatic control when power is restored. If the valve has no recycling feature, or if power is off for a prolonged period, close the valve manually.

d. Oil motorized valves at the beginning of each heating season and periodically during the season. Use high grade fine oil, but use it sparingly. Do not allow oil to reach electrical contacts and switches.

e. Clean solenoid valves thoroughly at the beginning of each heating season to remove any accumulated sediment which may impair operation. To clean, use safety solvent or similar high grade cleaning fluid and dry with an air hose, or wipe dry with a lintfree cloth. This applies also to pilot valves used on diaphragm valves, if the pilot valves are of the solenoid type.

f. Where gas appear to contain oil or sediment in perceptible quantity, install a suitable filter ahead of the pressure regulator.

7-11. Limit controls.

Limit controls shut down the heating equipment when the heating medium temperature or pressure becomes excessive. In electrical control systems, the limit control is an electric switch which normally is installed in series with the thermostat and the primary control. When either the thermostat or the limit control breaks the circuit, the flow of current through the primary control is interrupted to deactivate the heating system. In pneumatic systems, the limit control modifies or blocks the control air pressure sent to the primary control.

a. Limit and fan controls for forced warm-air. Occasionally a separate limit control and separate fan control are found on a forced warm air installation. Generally, the two will be included in a combination furnace control, having either a single common actuating element or a separate element for each switch (figure 7-8). Installation and operation procedures are described below.

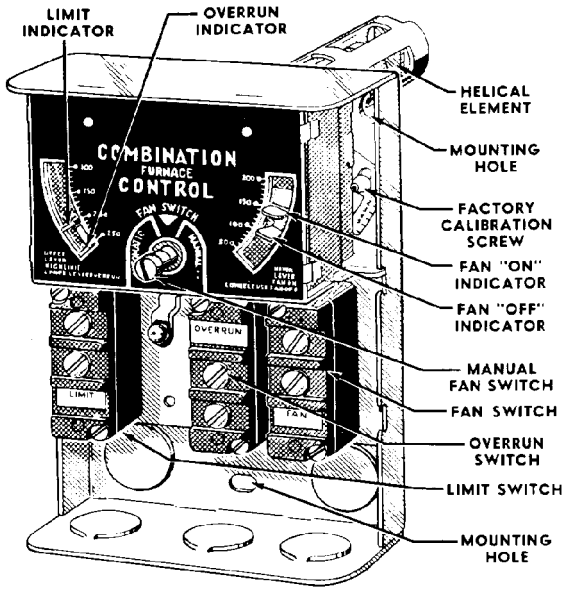

Figure 7-8. Combination fan and limit control.

(1) When installing either the single or combination control be sure that in the operating position no portion of the actuating element or elements touches the crown sheet. Install the element so that effects of radiant heat are kept to a minimum.

(2) Install the element so that it will be subjected to rapid temperature changes in the furnace. Do not install the element where it will be affected

by cold air returns or where circulation of air around it is restricted by baffles or deflecting fins.

(3) Use a swivel mounting bracket if space permits. If the control must be mounted flush on the furnace, be sure that an insulator, ½ inch thick if possible, is placed between the furnace and the control. It is important to limit the temperature inside the control to 150F if possible, to prevent damage to switches and maintain the electrical rating of the load contacts.

(4) For maximum efficiency and comfort, the fan switch setting should be as low as possible without discharge of cold air. Set the "fan on" point to approximately 115F and the "fan off' point to approximately l00F. A little experimentation will provide suitable settings, but the difference between "fan on" and "fan off' should be between 10F and 20F.

(5) For most installations, a limit switch setting of 175F is satisfactory. Improved efficiency in operation of heating equipment is attained by keeping the limit setting as low as possible without causing too frequent shut-down from bonnet temperature control.

(6) After setting and adjusting, be sure to replace the cover. This protects the mechanism and discourages unauthorized tampering with settings.

(7) Do not oil or lubricate combination fan and limit controls.

(8) Do not repair combination controls and do not replace switches on the job. In case of trouble, install a control from replacement stocks.

b. Limit controls for hot water. The high limit control for a hot water installation, whether forced or gravity, is commonly called an aquastat. Aquastats are either of the surface mounting or immersion type. Regardless of the type, the function is to prevent steaming of boiler water and to eliminate unnecessary firing.

(1) If limit controls are of the mercury type, be sure they are mounted level. Figures 7-9 and 7-10 are typical installation diagrams of immersion aquastats for hot water boilers.

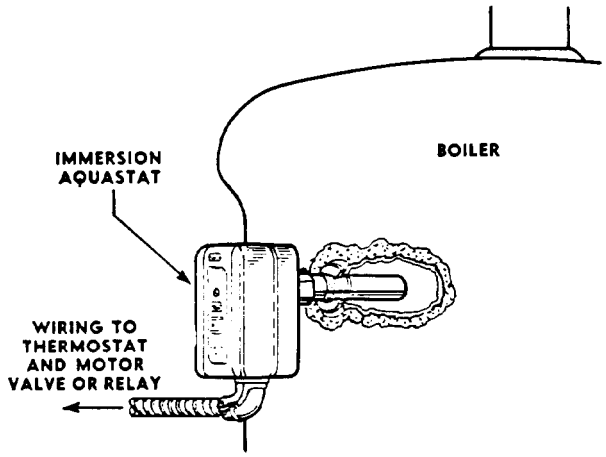

Figure 7–9. Immersion aquastat installation in hot water boiler.

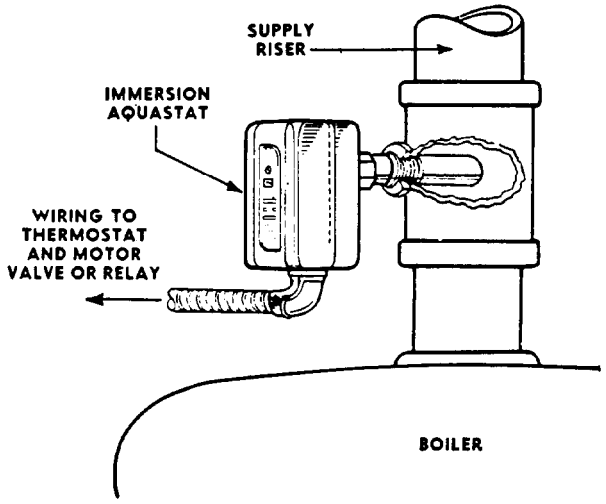

Figure 7–10. Immersion aquastat installation in vertical riser.

(2) Surface-mounted aquastats are not recommended for riser pipe sizes less than 1½ inches because of the small contact area. When riser pipe sizes run less than 1½ inches use an immersion type limit control.

c. Limit controls for steam boilers. Limit controls for steam are known as pressure controls. Care and operation for these controls is identical. Figures 7-11 shows a typical pressure control.

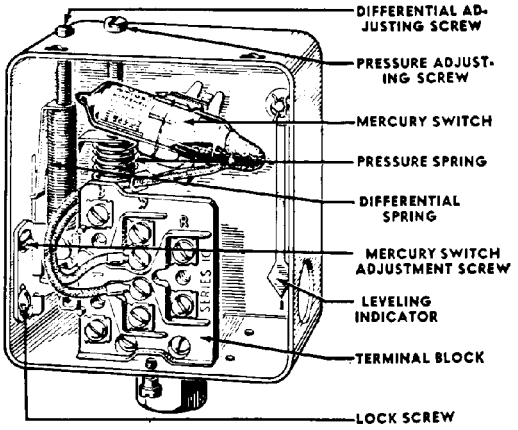

Figure 7-11. Pressure control for steam boiler.

(1) When installing, keep bellows from direct contact with steam. Some boiler waters are corrosive but by taking proper precautions, the life of brass or bronze bellows can be materially prolonged. To isolate the control, install a standard water siphon between the boiler and the control. Either a goose-neck or ball type siphon can be used. Figure 7-12 shows a typical installation of a pressure gauge and pressure control. Where excessive vibrations are encountered, mount the pressure control remotely from the boiler on a solid mounting with a suitable piping connection between. Pressure controls located remotely from the boiler must be installed at a slightly higher level than when mounted as shown in figure 7-12, and piping must be properly pitched to drain all condensate back into the boiler. Always connect a siphon between the pressure control and boiler.

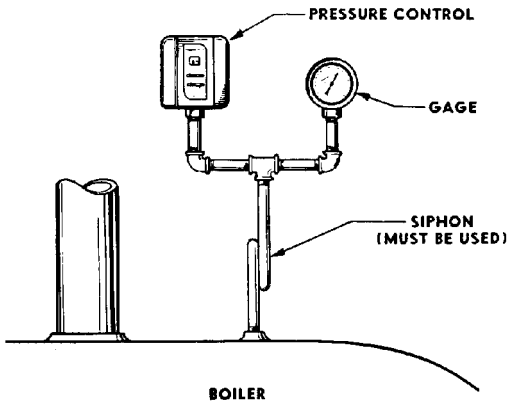

Figure 7-12. Pressure control on T-mounting.

(2) If a mercury type switch control is used, be sure that it is mounted level, and that the gooseneck siphon, if this type is used, has its loop extending in toward the back of the control. This will prevent expansion and contraction of the siphon from affecting the level of the control.

(3) A pressure control can be mounted either on a "T" along with the pressure gauge on a pressure gauge tapping as shown in figure 7-12 or it can be mounted on the low water cut-out provided by some manufacturers. Apply pipe dope to male threads only and leave the first two threads bare.

7-12. Safety pilot and pilotstat maintenance.

Automatic pilots and pilotstats for gas burners may be considered as limit controls. Their function is one of safety, to prevent the main gas valve from opening unless the pilot burner is lighted. Therefore, it is imperative that the pilot light burn at all times when operation of the gas burner is expected.

a. If the pilot light has a tendency to be extinguished between periods of operation of the main burner, check the gas pressure regulator to be sure it does not allow too great a variation in pressure at the burner. Also check to see that the flame is of the recommended height and has the proper mixture of air.

b. When installing be sure that the proper opening is used. Usually two sizes are specified, one for natural gas and one for manufactured gas. Follow manufacturer's recommendations in this regard.

c. Be sure that impingment of the flame against the sensing element is in accordance with the manufacturer's recommendation.

d. On thermocouple types, if the pilot flame appears to be satisfactory, but the pilotstat fails to open the main valve, check the voltage generated by the thermocouple by means of a millivoltmeter. The thermocouple should generate approximately 30 millivolts.

e. Do not kink or place too sharp bends in the thermocouple leads.

f. Be sure thermocouple connections are clean and drawn up tight to assure proper electrical connection.

7-13. Auxiliary controls.

Auxiliary controls include all controls not classified above. Among them are single flow control valves, cut-offs, outside temperature controls, combustion safeguards, etc.

a. Combustion safeguards. Combustion safeguards shut off the firing equipment if the flame is prematurely extinguished. There are several types, among them the following:

(1) *Stack switch.* The stack switch is the simplest combustion control. It consists of a hellicoi-

dal, bimetallic element inserted in the smoke pipe or breeching. The hot flue gas causes the helix to rotate a small shaft which closes and maintains a switch circuit. The helix opens the switch and shuts off the burner when any appreciable drop in gas temperature occurs. The stack switch is wellsuited to small boilers, but is slow-acting in large ones. The speed at which a stack switch reacts depends on the length of travel and velocity of the stack gases. A stack switch can be used with a primary control.

(2) *Protectostat.* This is a fast-acting, flame-failure control. It consists of a cast iron housing containing a diaphragm; it is coated black for maximum heat absorption. The protectostat is located on the boiler front so that it "looks" at the fire. When the fuel oil or gas is ignited, the diaphragm expands promptly and closes its switch contacts; when the flame is extinguished, the diaphragm contracts very rapidly and breaks the circuit. This control is suitable for a fixed-size flame with intermittent operation.

(3) *Photoelectric eye.* There are several types of photoelectric eyes. These controls act instantaneously to break a circuit when the flame fails. The electric eye is sighted at the flame and responds rapidly when the flame fails. It can be used with a primary control.

b. Low-water cutoffs. A low water cut-off is a switch which breaks an electrical circuit to stop operation of the firing equipment when the boiler water drops to a predetermined low level. A float mechanism which responds to boiler water level actuates the electrical low water cut-off switch. Steam boilers require two independent cut-offs, with separate connections for blowdown valving and piping. Hot water boilers require only low water cutoff.

c. Feed water regulators. Feedwater regulators maintain a relatively constant water level in steam boilers, regardless of load fluctuations. The float switch is a commonly used feedwater regulator. It consists of a float chamber so connected to the boiler that its mean water level corresponds to that of the boiler. When operating, the float switch follows the water level and makes or breaks an electric circuit (with a switch) whenever the boiler water level indicates. When a low-water level closes the switch, a feedwater pump begins to inject water into the boiler. When the high water level is reached, the switch opens and the pump stops. In this way, the float switch keeps the water level between the limits recommended by the manufacturer.

d. Draft controllers. The barometric damper is the simplest type of draft controller. It is usually located on the smoke pipe or breeching but can be placed at the base of the stack or chimney. It consists of a balanced swinging damper which is sensitive to changes in the draft intensity. The swinging damper can be adjusted by weight loading to maintain the desired draft in the combustion chamber. This controller acts as a balanced air valve which admits air to the flue pipe to maintain a constant draft in the furnace. It is well-suited for small boilers.

e. Smoke alarms. A typical alarm consists of a photoelectric cell, mounted on the side of the smoke breeching, which sights through the breeching to an electric light bulb mounted on the opposite side. Any smoke passing through the breeching decreases the amount of light intensity acting on the photoelectric cell. When this occurs, the cell changes the electric current to its signal box and the signal box flashes a warning light, sounds an alarm, or does both. These controls are not particularly useful when the top of the stack is not visible from the boiler room.